PATENT APPLICATION
Attorney Dock t No. D/A0888

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s): Hany Aziz et al.
Application No.: 09/935,031
Filed: 8/22/2001
Confirmation Number: 9210
Examiner: Jason Phinney
Art Unit: 2879
Title: OLEDS HAVING LIGHT ABSORBING ELECTRODE

CERTIFICATE OF MAILING

I hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, on

11/21/2003
(Date of deposit)

Francie S. LePore
Francie S. LéPore

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

DECLARATION UNDER 37 CFR 1.131

We, Hany Aziz, Nan-Xing Hu, Zoran D. Popovic, and James M. Duff, hereby declare as follows:

1. We are the listed inventors in the above-identified patent application.

2. We have reviewed O. Renault et al., "A low reflectivity multilayer cathode for organic light-emitting diodes," *Thin Solid Films*, Vol. 379, pp. 195-198 (December 8, 2000).

3. Prior to December 8, 2000 but subsequent to January 1, 1998 (referred herein as "Prior Time Period"), our invention as claimed in the above-identified patent application was conceived and reduced to practice in Canada.

4. As evidence of conception and reduction to practice during the Prior Time Period, we are attaching a copy of four (4) pages from our invention

proposal which describes embodiment(s) of the present invention, where those four (4) pages were completed and signed and dated by us (and also signed and dated by a witness) during the Prior Time Period. Any blanked out dates in said invention proposal are all during the Prior Time Period.

5. We hereby declare that all statements made herein of our own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Respectfully submitted,

Hany Aziz
Date: Oct. 22nd 2003.

Nan-Xing Hu
Date: Oct. 22, 2003

Zoran D. Popovic
Date: October 22, 2003.

James M. Duff
Date: Oct 23/03

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Invention Proposal

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Signed hard copy To: Xerox Intellectual Property Law Department

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	Proposal Submitted By (Please use legal name) Full First Name, Middle, Last		Employee No.	
1	**Hany Aziz** XRC		Industrial Postdoctoral Fellow	
	Organization (Unit/Div./Dept./Section)	Electronic Mail Address	Building No./ Mail Stop	Extension
	XRCC/MI	hany.aziz@crt.xerox.com	XRCC/3	440
2	Proposal Submitted By (Please use legal name) Full First Name, Middle, Last		Employee No.	
	Nan-Xing Hu		042925	
	Organization (Unit/Div./Dept./Section)	Electronic Mail Address	Building No./ Mail Stop	Extension
	XRCC/ MD&S	Nan-Xing.Hu@crt.xerox.com	XRCC/10	320
3	Proposal Submitted By (Please use legal name) Full First Name, Middle, Last		Employee No.	
	Zoran D. Popovic		3596	
	Organization (Unit/Div./Dept./Section)	Electronic Mail Address	Building No./ Mail Stop	Extension
	XRCC/MI	Zoran.popovic@crt.xerox.com	XRCC/3	421
4	Proposal Submitted By (Please use legal name) Full First Name, Middle, Last		Employee No.	
	Jim Duff James M			
	Organization (Unit/Div./Dept./Section)	Electronic Mail Address	Building No./ Mail Stop	Extension
	XRCC/ MD&S	Jim.Duff@crt.xerox.com	XRCC/10	335

* If space for additional submitters is required, please use another sheet; and attach any supplementary Comments.

Manager	**Electronic Mail Address**	**Bldg. No./MS**
Ah-Mee Hor	Ah-Mee.Hor@crt.xerox.com	XRCC/3
Paul Smith	Paul.Smith@crt.xerox.com	XRCC/10

Technical Category (see attached list)	**Name of Xerox Program** (if any)
3.16 Display Devices, 4.7 Electronic Materials, 5.2 Manufacturing Processes	EL Project

Opportunity for licensing revenue Who could be interested in it? How is this better than alternatives?

Yes. Producers of Electronic Displays. The invention embodies a dark non-reflective cathode structure for use in organic light emitting devices (OLEDs) in order to enable high contrast displays.

Descriptive title of invention

Dark non-reflective cathode configuration for organic light emitting devices (OLEDs).

Describe the problem How was this problem tackled before your invention?

Organic Light Emitting Devices (OLEDs) represent a promising technology for display applications. A typical device structure consists of a transparent substrate, a transparent front electrode (usually serving as a hole-injecting anode, electroluminescent organic layer(s), and a back electrode (serving as an electron-injecting cathode). In order to facilitate the electron injection from the top electrode into the electroluminescent layers, it is required that the back electrode be made of a low work function metal, and therefore is highly reflective. When a voltage is applied across the electrodes, light is emitted from the electroluminescent layer(s) and through the transparent anode and substrate, to reach the observer. When viewed under high ambient illumination, the reflective back electrode reflects a substantial amount of the ambient illumination to the observer, which results in higher ratios of the reflected illumination compared to device own emission thus leading to "washout" of the displayed image. In order to improve the contrast of electroluminescent displays in general, light absorbing layers (US patent no. 4,287,449) or optical interference members (US patent no. 5,049,780) are used to reduce the ambient illumination reflection, both of which involve the use of optical films made of materials that are generally non-conductive. That puts limitations on their applicability to OLEDs, which, unlike inorganic electroluminescent phosphor

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devices, require the direct injection of charges from the electrodes to the electroluminescent layer(s). Besides, fabricating these films often requires using sputtering or electron beam evaporation techniques which would require additional instrumentation to the otherwise relatively simple fabrication process of OLEDs (by thermal evaporation or spin coating). In addition, in case of the optical interference members, stringent control of film thicknesses and deposition conditions are necessary to obtain the desired interference effects, and the resulting improvement in display contrast is inevitably dependent on the viewing angle.

Summary of the invention Describe briefly what the invention is and how it works in 5 –8 lines.

The present invention describes a dark non-reflective cathode configuration that can be used in OLEDs to eliminate or at least significantly reduce the reflected ambient illumination, and therefore enhances display contrast and visibility even in high ambient illumination conditions. The cathode configuration comprises a very thin layer (<10 nm thick) of a low work function material, that can be chosen as required to achieve the desired electron-injection properties (e.g. Mg:Ag), followed by a thick layer (>50 nm thick) of a light absorbing material. The light absorbing layer can be optionally coated with a protective metallic layer (e.g. Ag). To facilitate device fabrication, the material used in the light absorbing material can be selected so as to enable its deposition by thermal evaporation in order to utilize the same instrumentation used in fabricating the other layers of the OLEDs (e.g. an organic dark-colored material). Preferably, this material is also electrically conductive (e.g. C_{60}) in order to reduce the sheet resistance of the cathode.

Describe your invention Describe how to make and use the invention and it's novel embodiments. Cover the process, method, materials with sketches, flow charts, usage etc. What are the advantages of your invention for Xerox?

An OLED with a cathode configuration according to the proposed invention will be of structure as shown in figure 1.

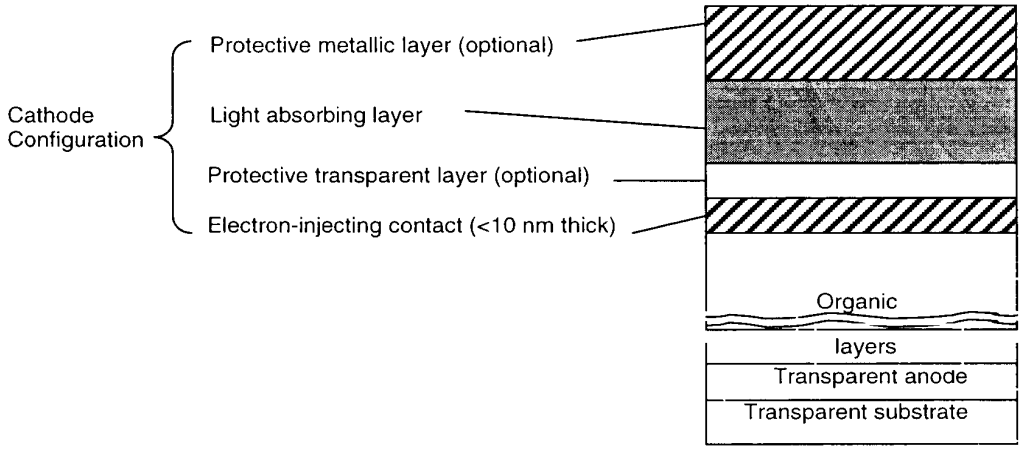

Figure 1

The electron-injecting contact is typically made of a layer of a low work function metal (e.g. Mg:Ag) that is thick enough to achieve low sheet resistance (in the order of few tens of ohms per square or less) but thin enough to have a limited optical reflectivity (i.e. such that > 50% optical transmission can occur). The thickness of the electron-injecting contact is typically in the range of 3-10 nm, and preferably about 4-5 nm thick. The light absorbing layer can be made of any light absorbing material, preferably one that can be deposited on the electron-injecting contact by thermal evaporation in vacuum in order to utilize the same instrumentation used in fabricating the other layers of the OLEDs. It is also desirable that the light absorbing layer be electrically conductive in order to reduce the sheet resistance of the cathode configuration. To this extent, the light absorbing layer is preferably made of a conductive light absorbing organic material (e.g. C_{60}) or a mixture of a light absorbing organic material (e.g. black pigment) and a conductive material. The thickness of the light absorbing layer should be such that at least about 90% extinction of the transmitted light occurs in the layer. The light absorbing layer can be optionally coated with a protective metallic layer. In addition to providing protection, this layer can be

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used, in combination with a conductive light absorbing layer, in substantially reducing the sheet resistance of the cathode configuration, and thus becomes particularly important in large area displays. A protective transparent layer can optionally be inserted between the electron-injecting contact and the light absorbing material to avoid any undesirable reactions between the two layers, especially that the metals used in the contact layer are usually highly reactive.

A prototype OLED with cathode of structure according to the present invention were fabricated and evaluated. In these devices, *N,N'*-di(naphthalene-1-yl)-*N,N'*-diphenyl-benzidine (NPB) and Tris (8-hydroxyquinoline) aluminum (AlQ3) were used as the hole transport material and the electron transport material , respectively. The NPB layer followed by the AlQ3 layer were deposited using vacuum evaporation on a transparent substrate pre-coated with an ITO anode. Following the deposition of the AlQ3 layer, the electron-injecting contact layer (4 nm thick) of Mg: Ag (9:1 by volume) was deposited by evaporating pure Mg and Ag metals from separate sources. Following the Mg: Ag, a 500 nm thick protective layer of SiO was deposited. Next, a 500 nm thick layer of a black pigment material, Bis (1,8-Naphthimidazo) perinone, acting as the light absorbing layer, was deposited. Finally a 200 nm thick Ag protective layer was deposited. All OLED layers, including the cathode layers, were fabricated by thermal evaporation in vacuum (~ $5x10^{-6}$ torr.) in the same pump down cycle. Visual examination of the devices revealed negligible reflectivity of ambient illumination. When operated under 7 volts, OLED emission demonstrated excellent visibility, independent of the viewing angle, under strong ambient illumination from a 200W flood light source placed about 15 cms apart from the OLED. On the other hand, a similar OLED but with a conventional reflective cathode, also operated under 7 volts, was almost invisible under same ambient illumination conditions.

In general, the disclosed cathode configuration can also be used for OLEDs based on either small molecules or polymeric materials. The concept can be also used for an anode rather than a cathode configuration in OLED structures involving transparent cathodes and/or reflective anodes or substrates or in inverted OLED structures.

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People List names of others known to have worked on this or a similar invention

Related concepts Check the Xerox Patent data base at http://comip.wrc.xerox.com/comip/icbuhome.nsf
What have you found in a data base search of the topic? Give patent or IP number of the most relevant items.

Prototype Has a model, a prototype, or experiment of the invention been built, made, run or tested ? ☐ Yes ☐ No

Yes. The proposed cathode configuration has been tested on prototype OLEDs as discussed above .

Xerox product Is the invention used by Xerox or is there a definite plan for use in a future product(s) ? ☐ Yes ☐ No
If so, please identify the program(s) or product(s), and introduction dates:

No. However, this process will provide Xerox with licensing opportunities.

Disclosures Has this concept been disclosed to vendors, consultants, outside parties, partners, etc? Indicate the date(s) of any previous or planned future disclosure external to Xerox, and identify the type of disclosure (by agreement, demonstration, paper or presentation given, market probe, published article, etc., and if convenient, please provide a copy of the agreement, paper or article):

No.

Outside funding Source of outside funding, if any:

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